Journal of Trends in the Development of Machinery and Associated Technology
Vol. 19, No. 1, 2015, ISSN 2303-4009 (online), p.p. 161-164

NEW DESIGN OF THE SOWER SEEDING UNIT FOR PRECISE ORGANIC AGRICULTURE

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ABSTRACT
In order to replace chemical crop treatment with mechanical one, a new line of agricultural machines is proposed and patented. A line consists of seeder and cultivator which are based on a common principle of precise geometric plant positioning pattern. This paper discusses design issues arose in development of the seeder unit. Those issues include adoption of driving mechanism and dimensioning and placement problems which have to be solved in order to assure proper device functioning.
Keywords: mechanical crop treatment, seeder, design

1. INTRODUCTION

In order to assure high production rates, temporary industrial agricultural production highly relies on intensive use of agrochemicals - herbicides and pesticides. Widely accepted concept of sustainable development, however, realizes that production and use of chemicals deteriorate quality of produced food and environment globally, and that in a long run, organic agriculture will be the only acceptable way [1,2]. The most important issue in organic agriculture is mechanical cultivating as a way of weed control [3], which has to replace manual labor to maintain significant profitability rate.
Weed treatment is difficult task including need for inter-row and intra-row cultivating in vicinity of plant [4]. In order to achieve precision and avoid plant damage, a number of highly sophisticated devices have been developed in recent period [5,6,7], but none of them is commercially available, mainly because they could not prove economic gains.
An innovative concept is developed and patented by dipl. eng. R. Matić and supported by Agricultural and Technical faculty in Novi Sad. Its main advantage is simplicity and lack of complicated devices such as hi-tech sensors and GP. It is based on connecting seeding and weeding operations in a precise prescribed geometric plant placement pattern [8]. In this way, weeding can be easily monitored, specially its intra-row component. By "reading" single row with simple equipment, it is possible to treat a large number of rows with standardized block of tools.

2. SEEDER STRUCTURE CONCEPT

Common seeder unit has a device which enables seeds to be uniformly dispensed in time, meaning that, with uniform tractor speed, some kind of plant placement precision exists. The main problem is that a path between the dispenser and the ground hole is quite long, thus the seed can be jammed in the way or bounce and its actual position can significantly differ from the projected one. In order to avoid this problem, proposed seeder consists of two units: common feeding unit which takes the seed from the container and place it in a dispense unit which gently lay down the seed on the ground. With the addition of dispense unit the precise geometric pattern of seed is ensured.
Main structure of the dispense unit is a set of *n* pockets. They are arranged in a circular pattern which is rotating, thus enabling them to be filled with the seed in upmost position and emptied in a down most one. There are two main issues regarding design of the dispense unit.

3. DESIGN ISSUES

3.1. Driving mechanism

The first problem regards mechanism which can rotate a set of pockets while keeping them in upward position at all times. A proposed mechanism is based on joint fourbar parallelogram – a simple mechanism of four links of which opposite two has the same length, and are interconnected with revolute joints. It is known that input (2) and output (4) links can make a full rotation and that floating link (3) is at all time parallel to the ground link (1) (Fig. 1a). Weakness of this mechanism is a singular point – a position when all four links are collinear, in which the movement of output link is not determined. However, in our application this problem does not occur. A number of mechanisms (their input and output links) are fixed together (Fig. 1b) so that when a singular point occurs in one mechanism the others will not face it and the movement of output link will be determined.

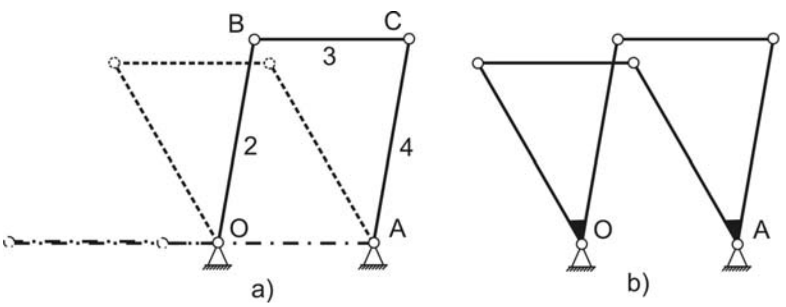


Figure 1. Driving mechanism

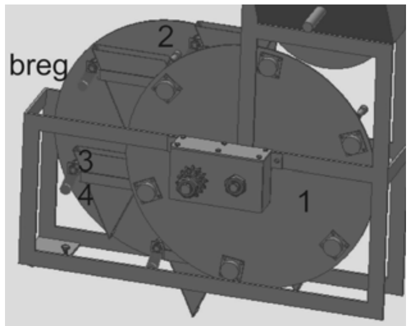


Figure 2. Pocket assembly

In actual design (Fig.2), two shifted circular plates (*1* and *2*) of the same diameter present input and output links with equally spaced bearings at brim. The connecting bar (*4*) which is joined to corresponding bearings on both plates presents pocket (*3*) holder. The set of *n* pockets is placed between plates.
There is also a question of driving input. The mechanism has one D.O.F, which means that only one of the plates has to be driven. In this case, on the other hand, having a number of mechanisms tied together implies serious question of precision. Parallel movement of links and equal angular velocity of input and output links are typical only for high precision equality of links length which can hardly be achieved. Therefore, we adopted that both plates should be driven with the same speed.

3.2. Number of pockets

Another issue regards number of pockets and its relation with plate diameter. The relevance of pocket number can be shown by kinematic analysis of power train which drives the seeder mechanism.
As can be seen on the Fig. 3, rotation of seeder wheel is transmitted to the feeding and dispensing unit through the chain drive.

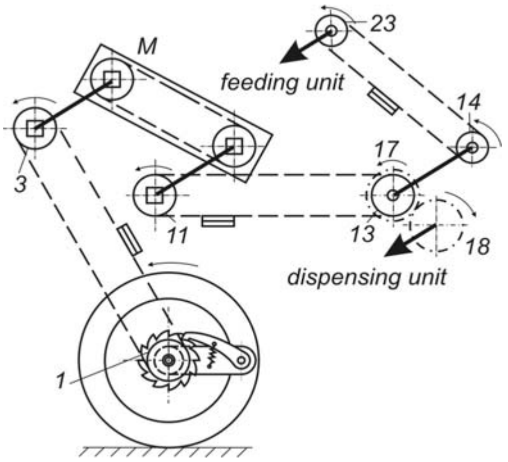


Figure 3. Seeder drive

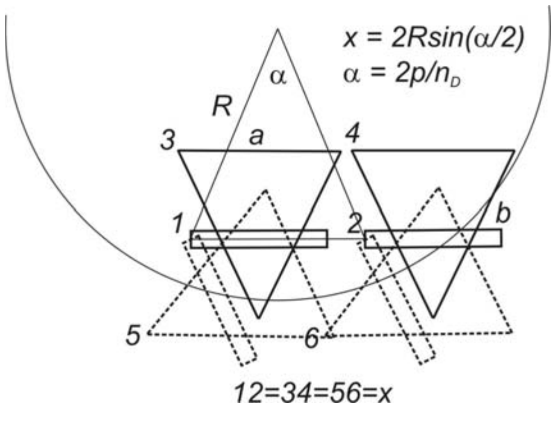


Figure 4. Pocket collision analysis

Common drive train consists of chain sprocket pairs *1-3* and *11-13* and chain box *M*. From sprocket *13*, movement is transmitted to feeding unit by chain pair *14-23*, and to dispensing unit by gear pair *17-18* (Fig. 3). In this way, corresponding angular velocities are:

$$\omega_F = \omega_T \cdot \frac{z_1}{z_3} \cdot \frac{z_{11}}{z_{13}} \cdot i_M \cdot \frac{z_{14}}{z_{23}} \tag{1}$$

$$\omega_D = \omega_T \cdot \frac{z_1}{z_3} \cdot \frac{z_{11}}{z_{13}} \cdot i_M \cdot \frac{z_{17}}{z_{18}} \tag{2}$$

where

- ω_F and ω_D are angular velocities of feeder and dispenser unit
- ω_T is angular velocity of the seeder wheel
- i_M is velocity ratio of the chain box reducer (input/output)

Having in mind that every seed released by the feeder has to be received by one dispenser pocket, ratio between n_F and n_D can be expressed by:

$$\frac{n_F}{n_D} = \frac{z_{23}}{z_{14}} \tag{3}$$

where

- n_F is number of holes in feeder plate
- n_D is number of pockets in dispenser unit
- gear ratio $z_{17}/z_{18} = 1$

Different number of dispenser pockets gives some options in choosing different feeder plates. It contributes to broader range of plant interval. This interval can be expressed by:

$$L = R_T \cdot \omega_T \cdot \frac{2\pi}{n_D \cdot \omega_D} = R_T \cdot \frac{z_3}{z_1} \cdot \frac{z_{13}}{z_{11}} \cdot \frac{1}{i_M} \cdot \frac{z_{18}}{z_{17}} \cdot \frac{2\pi}{n_D} \tag{4}$$

where R_T is seeder wheel radius.

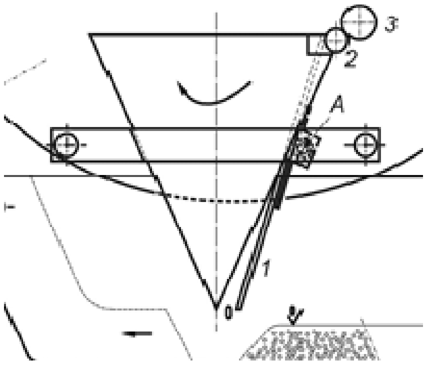
For one installation, gear number is constant and the plant interval depends primarily on reducer ratio i_M. Chain box commonly includes 4 and 3 sprockets on input and output shafts, giving 12 different ratios. If there is a possibility of dispenser change, the complexity of chain box can be reduced, or number of different plant intervals can be increased.

Therefore, there is a need for analysis of pocket set number and plate diameter. Theoretical relation can be observed on Fig. 4. Interaction between adjacent pockets can be represented using kinematical inversion – assuming that the plate is immobile and the pockets rotate around bearings (point *1* and *2*). It can be seen that critical positions are ones in which edges of two subsequent pockets are collinear. It can be concluded that the distance *x* (*1-2*), depending on plate diameter and angle α (number of pockets), must be greater than the longest edge of the pocket. At Fig. 4 pockets have different edges *a* and *b* ($b > a$). It can appear, looking the position when edges *a* are collinear (full line), that the design is not problematic, but when pockets are rotated to collinear position of edges *b* (dashed line) it is clear that they will collide.

There are two important remarks: *R* is not exact plate radius but rather the distance of connecting bar joint (*1*) from plate centre. The plate radius is definitely somewhat longer than this; There are also some issues regarding pocket and joint design, resulting in need to further increase plate radius according to theoretical value.Required pocket size *a* depends on seed dimensions, design and functional requirements (particularly necessary protrusion of pockets from plate area in upmost and down most position). It is estimated that 6 to 10 cm is sufficient dimension. General diameters of the plate are approx. 320, 400, 500 mm for 6, 8 and 12 pockets.

3.3. Pocket opening device

Another important dispenser functional issue is the opening of the pocket. The simplest design is to make one side of the pocket in shape of swinging door *1*. It can be seen on Fig. 5 with swinging axes *A* and activating knob *2*. Cam *3* on the plate collides with door knob *B* and forces it to swing and open. The most important issue is cam placement. Although it is fixed on the plate, cam position according to any pocket changes during the rotation. During the rotation it must not interfere with any connecting bar or pocket, except the intended knob of bottom placed pocket. Every pocket must have its own cam.



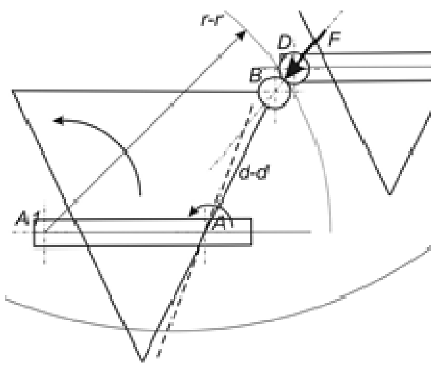


Figure 5. Pocket design *Figure 6. Pocket opening*

There is a very few cam positions that satisfy those constraints. The safest way is to put it exactly at the connecting bar joint of the next pocket. If connecting bars are properly placed and not interfere with adjacent pockets, it will also apply for the cam. In this situation, a contact between the cam and the knob will appear twice: ones in the intended position and once in a position shifted by half of the circle. Having in mind that the seed occupies the pocket only in half of its rotation, this other collision (and pocket opening) will not pose a problem. There is one more problem: mutual position of the knob and the cam at the collision moment. It is presented on Fig. 6, assuming that both parts have a circular shape (which is the simplest case). First, it is important to notice that, in order to collide during the rotation around *A1* (kinematic inversion), cam *D* must partially lie inside the circle *r-r*, above knob *B*. In position presented in the picture, the contact reaction (*F*) (passing through centres *B* and *D*) will force the door to swing in CCW direction – the one which will open the door. On the other hand, if the cam centre is positioned above the line *d-d* at the impact moment, the reaction will cause swinging in other direction, which will force the door bottom end toward the pocket. The position of centres at the collision moment depends on pocket size and shape and also the position of the cam. Having in mind all previous statements these parameters are pretty much defined and can not be significantly altered. However, collision position also depends on knob and cam diameters, so they can be parameters of choice in attempt to assure proper centres position.

4. CONCLUSION

A complete design process of seeder unit in a new line of agricultural machines is carried out. This process proved that the simple developed and patented functioning concept could not be translated into a working model without serious analysis like one presented in this paper. Design solutions can be found in [8]. This work is funded by the Provincial secretariat for science and technological development. Upon the virtual prototype developed in Autodesk/Inventor, the physical prototypes are under construction.

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